From Forest to Farmfields: Changes in Land Use in Undulating Terrain of Northeast Thailand at Different Scales during the Past Century(<Special Issue>Sustainable Agro-resources Management in the Mountainous Region of Mainland Southeast Asia)

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Southeast Asian Studies, Vol. 41, No. 4, March 2004

From Forest to Farmfields: Changes in Land Use in Undulating Terrain of Northeast Thailand at Different Scales during the Past Century

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Abstract

Contemporary land-use change during the past century in Northeast Thailand was analyzed at four socio-ecological scales: region, community, landscape and field plot. The main objectives were to elucidate factors influencing the change and identify effects of the change on the present land conditions. At all scales the land was transformed from forest to cultivated fields by pioneering farmers but such land transformation did not lead to rapid forest loss in the earlier subsistence economy period. Rapid forest loss only occurred after the economy became more commercialized with the expansion of cash crop cultivation in the early 1950s. Land transformation began in the lowland (prime areas for paddy fields) and expanded upward to the uplands. Population growth was the major factor for land-use change in the earlier stage while subsequently the growing commercialization of agriculture was the main factor. Changes in land use have resulted in degradation of land in the upland fields but not in the paddy fields. The upland fields have higher soil erosion and lower soil organic matter pools than the natural forest. The paddy fields, however, do not show indications of being degraded, probably because of their inherent soil properties and their location in the low-lying areas where they receive continuing in-flows of nutrients eroded from higher parts of the landscape. A number of measures to counter the land degradation are suggested including adopting of a more polycultural form of agriculture by integrating trees into agroecosystems at all scales. Such polycultural systems mimic the natural forest ecosystem which is more sustainable ecologically than monocultural systems. In addition, farmers in the Northeast should readopt some degree of subsistence-orientation which would increase the economic and social sustainability of Northeastern agriculture.

Keywords: agroecosystem, forest, land-use change, land degradation, spatial scales, sustainability, twentieth century, Northeast Thailand

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I Introduction

The study of land-use change is the analysis of past human interaction with the land that has brought about effects perceivable in the present. The history of land use of a geographical area within a predetermined time frame is investigated to bring about a clearer understanding of the present state of its land resources. The Northeast region occupies one-third of Thailand's land area (170,000 square kilometers) and is home to one-third of its population (approx. 20 million). Although it is the poorest region economically, it holds potential to be developed due to its vast area and large population. During the last century, however, its land resources, especially forest, soil, and water, have deteriorated. The area covered by forest declined from 90% in the 1930s to less than 14% today while soil degradation due to widely practiced forms of agricultural land use has brought about yield decline and a threat to long-term use of the land.

The objective of this paper is to analyze contemporary land-use change in the Northeast at various spatial scales. This analysis seeks to identify factors influencing the change and describe presently perceivable land conditions. In addition, some opportunities for future development are discussed.

II Methodology and Analytic Framework

In this study, land-use change in the Northeast is analysed at different spatial scales or levels in the agroecosystem hierarchy. Rambo [1991] proposed two parallel hierarchies, one ecological, the other social, for studies of agroecosystems in the Northeast. A somewhat similar approach is employed in this paper. In the ecosystem hierarchy, the systems in ascending order of spatial scale are field plot, landscape, watershed, river basin, continent, and the whole biosphere, while the farm household, village, district, province, nation, continent, and global system represent the ascending levels in the social-political-administrative system hierarchy. This set of parallel system hierarchies is used because there are discrepancies between the scales employed in ecological and social science analysis of agroecosystems. For example, the farm household, the lowest level in the social system hierarchy, is intermediate in spatial scale between the field plot and landscape levels of the ecological scale. Thus, it can be seen that the hierarchies of systems scale at some levels are not isomorphic.

In this paper, land-use change is described at two levels in the ecosystem hierarchy (plot and the landscape) and two levels in the social system hierarchy (the community and the region). Analyses of change at different scales can give a more comprehensive understanding than those conducted at a single scale. Analyses of land-use change at a macro level, such as the region, provide an overview of "when," "how much," and "how" changes

occurred, and also allow identification of prominent factors causing the changes. Analyses at a more micro level, such as a landscape, provide more detailed perspectives on land-use events that have occurred in a particular parcel of land. Information from both scales can be compared to reveal the inter-relationships among changes that have occurred at different levels. For example, analysis at the regional level might reveal that there is extensive land degradation in the region as a whole, but at the plot or landscape level it might be found that the degradation has occurred in only some types of fields (e.g., upland fields) but not in low-land fields. Similarly, it might be found that growth of population was a major force for change at the regional social scale but that, within specific individual communities population had stabilized and other factors, such as adoption of commercial agriculture, were the major force for change. Therefore, generalizations on land degradation should not be made across the board and recommendations of ways to rectify the situation should be restricted to specific levels in the systems hierarchy.

The regional level analysis employs secondary information available in the literature, while those at the community, landscape, and filed plot level are based on both the literature review and primary data obtained from our studied village of Kham Muang in Khon Kaen province.

The primary data at the village, landscape, and plot levels were obtained as a part of site characterization activities performed in 1997–98 followed by continuous monitoring until 2001, to describe and analyze biophysical, and socio-economic characteristics of the selected site for our research project entitled “Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand.” The study was conducted at three levels or spatial scales, i.e. village, landscape (mini-watershed), and field plot levels. The village-level study employed semi-structured interview technique which consists of many interviews of key informants including, among others, the village headman, assistant village headman, former principal of the village school, and some senior citizens who were knowledgeable about various physical, biological, and socio-economic aspects of the village. The landscape-level study employed a similar technique to that of the community level but the informants were those who actually cultivated the land selected for the study site and those in its vicinity. In addition, at the landscape level, data were collected using various types of technical instruments to make physical measurements, such as global positioning system (GPS) and a geological technique of seismography to identify the parent rocks of the study site, etc. The plot-level study employed observations, soil and plant sample collections for laboratory analyses, and physical measurements using various kinds of scientific field equipment.

The analytic framework of this paper (Fig. 1) is based on the contemporary land-use change during the past century occurring at all socio-ecological scales in Northeast Thailand. Distinct phases can be identified in the overall shift from forest to agricultural land use. During the transition between forest system and agricultural systems, many interactions among components belonging to the two types of ecosystem also occurred, for

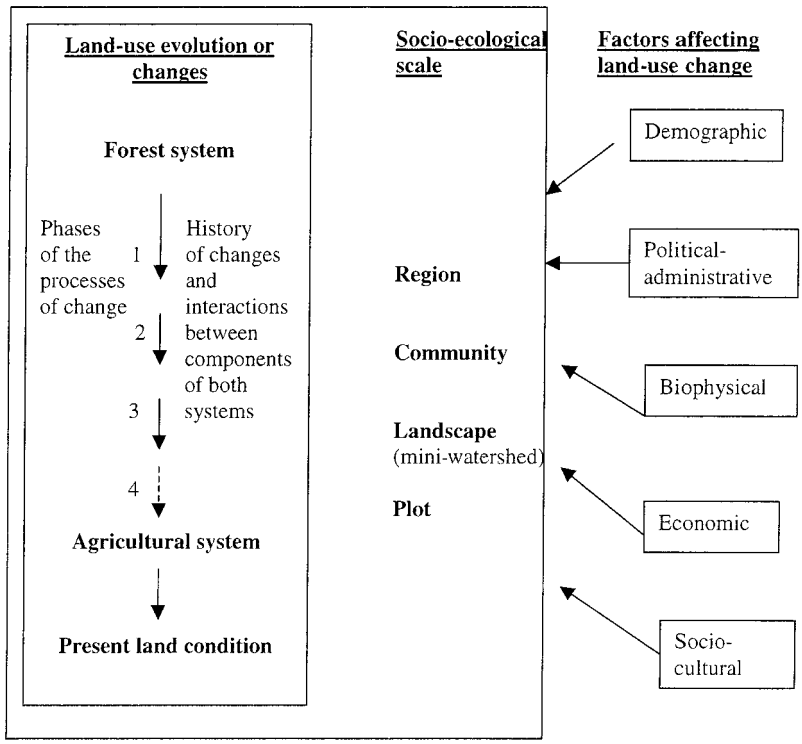

Fig. 1 Framework for the Analysis of Land-use Change in Northeast Thailand

example, people still obtained a lot of forest products for their livelihoods during earlier stages of land-use evolution, and livestock raising relied more on grazing in the forest in an early stage than in a later stage. We have also tried to identify prominent factors affecting the land-use changes at various scales. Some of the possible factors are of demographic nature as population growth has been found to be a most influential factor for peoples' relocation to find new land to make their living, while physical and biological factors are probably related to the population growth when people found that the land they had was no longer adequately productive and other physical and biological resources were no longer available in sufficient quantities to support their growing families. The political and administrative factors at national and local levels can be highly influential in shaping land use through issuing policy, enacting laws and rules of conduct that can directly or indirectly favor one kind of land use over others. For example, the law that prevents secure land ownership does not encourage sustainable land use, e.g. people tend to plant short-term crops in recently cleared land and do not want to plant perennial crops, such as trees, as they cannot be sure that in the future they will be permitted to harvest their crops. Economic factors tend to exert their influence from higher levels in the system hierarchy, e.g., global and national, to lower levels, e.g., regional, community and household. The change from a subsistence-

oriented economy to a market-oriented economy is a case in point. The force of market economy infiltrated into Thailand from international market, for example the demand for cassava as a raw material to produce animal feeds by European market. The economic factor to a large extent influences the political factor. For example, the government, in a drive to get export earnings, reshaped its policies to favor the cultivation of cash crops. This resulted in rapid decrease of forested areas that were turned into cultivated fields in the Northeast. Lastly, sociocultural factors related to the Northeastern people's way of thinking, their beliefs and their customs as derived through generations, play an important role in land-use change. Some studies and accounts [e.g., Fukui 1993] have presented the Northeastern people as pioneers who venture into unknown frontiers in the hope of finding better living situations. All of the above mentioned factors not only influence the land-use change on their own, but also interact with each other in complex ways. Overall, however, they have acted so that land-use change in the Northeast in most respects has resulted in degradation of much of the cultivated land. In this paper we will examine the changes that have occurred at different levels in the socio-ecological hierarchy, beginning with a regional overview and then examining changes at the community, landscape, and field plot level in turn.

III Land-use Change in the Northeast at the Regional Level

Contemporary land use in the Northeastern region of Thailand has been a subject of research since the 1930s. Before it was brought under Thai administration in 1830 the region had a very sparse population [Dixon 1978] and the land was covered with dense forest. As late as 1930 only 6.9% of land area was occupied by agriculture which was practically all irrigated [Zimmerman 1937, see also Fukui *et al*. 2000]. The rest of the land was under forest. Zimmerman also pointed out the high potential for expansion of non-irrigated agriculture in the Northeast and this has become the dominant form of Northeast agriculture today. Land-use change in the Northeast is characterized by deforestation due mainly to agricultural expansion which is a common feature of the land-use development in the Mainland Southeast Asia. The greatest pressure for land conversion in Mainland Southeast Asia during 1880–1980 derived from pioneer peasant farmers clearing land for wet rice paddies [Richards and Flint 1994].

Rice is the primary subsistence staple for the population of the Northeast. Production of adequate rice for household consumption is a main factor of food security of the region's population. Rice paddies were usually established as soon as a group of migrants decided to settle in a new location that they found suitable. The first paddies to be established were usually located in the low-lying parts of the undulating terrain that is the dominant land form [KKU-Ford Cropping Systems Research Project 1982]. Preferred sites were the bottom part of a mini-watershed or in a stream channel where water is amply available and the soils are of alluvium deposits which are more fertile than the typically sandy textured soils of upper-

lying areas. The villages of the region are usually located on higher lands adjacent to rice paddies in the low-lying areas.

There are conflicting reports about the order in which different types of fields were brought into cultivation in the initial stage of village establishment. Theerasasawat *et al.* [1990] reports that upland rice was cultivated before paddies were constructed because it does not require elaborate bund construction and removal of tree stumps. It was only at a later stage, when weed infestation became overwhelming, that planting of paddy rice began. Other reports, however, claim that wet rice was cultivated first in the low-lying area in the initial stage of settlement establishment [e.g., Dixon 1978]. Recent work on evolution of rain-fed rice cultivation in Northeast Thailand has highlighted the existence of earthen dams during the early period of twentieth century (approx. 1902–41). The dams were constructed across stream channels for the purpose of diverting storm-flow into adjacent paddy fields [Fukui *et al.* 2000]. The diverted or spilled-over water from the dams only reached paddy fields situated in low-lying bottom land of the undulating terrain. This evidence seems to support other studies which found that lowland wet rice cultivation was established prior to other forms of rice cultivation.

Upland crops are grown on higher areas where submerged conditions do not take place. In the early period of a settlement establishment, subsistence upland crops like native cotton, kenaf, and upland rice were grown. Shifting cultivation in the upper-lying areas was reported to be commonly practiced during the 1930s and 1940s [Pendleton 1943]. This was when population pressure on land was still not heavy. Shifting cultivation was practiced on both steep hillsides and upper-lying lands adjacent to the settlement (village). However, Pendleton [*ibid.*] pointed out that shifting cultivation on the latter land did not give as good yields as that on the hill slopes. By the early 1960s, the area under shifting cultivation was reported to be one million hectares [Gartner and Beuschel (1963) cited in Donner 1978]. However, it appears that the practice of shifting cultivation had declined long before the 1960s and by 1953 the first farm survey showed that only 3.5% of the region's farm households claimed to practice shifting cultivation [Thomas 1988].

Livestock (cattle and buffaloes) raising is another feature of land use in the Northeast. The Northeast used to export large numbers of cattle and buffalo to central Thailand. Herdsmen brought them south along small trails which were the only means of transport in the past [*ibid.*]. Cattle raising was a prominent land use in the 1930s and 1940s. According to Pendleton [1943] each household had several head. They grazed on the green and dry grasses in the open forests and some palatable trees and shrubs. After rice harvesting they also grazed on the rice stubble. Rice straw was also kept for their feeding in the dry season. The livestock provided manure that was highly valued by villagers for soil improvement. Since they were kept in pens underneath the house at night, large amounts of manure accumulated in the pen. Pendleton [*ibid.*], being a soil scientist, emphasized the importance of manure as a soil amendment used by farmers. Cattle manure in the past was mainly used on mulberry bushes (for silk worm feed) and tobacco grown for home consumption; any extra

manure was also used on rice nursery beds [*ibid.*]. Much research on effects of cattle manure on the fertility of the sandy acid soils of the Northeast has shown conclusively that it improves soil fertility by changing various chemical properties of the soil including increasing soil pH, capacity to retain cation nutrients, and contents of various major nutrients [e.g. Vityakon *et al.* 1988a].

The forests surrounding villages of the Northeast play very important roles in villagers' livelihoods. Villagers obtain construction materials, fuel, food (fruits, vegetables, nuts, and herbs), medicines, dyes, resins, and many other products from the forests [Wacharakitti (1987) and Dixon (1978) cited in Thomas 1988]. Trees, partly remnants of the forests that had been cleared for cultivation, in cultivated fields are a prominent feature of the Northeast landscape. Trees are found in both paddy and upland fields. Pendleton [1943] suggested that farmers did not cut more trees than was necessary because they knew that trees can fertilize the soils. This benefit has been confirmed in research on the contribution of trees, especially its litter fall, to soil fertility in areas close to the trees, i.e. under trees' canopies [Sae-Lee *et al.* 1992] and in the fields where trees stand [Vityakon *et al.* 1988b]. Later research has thrown additional light on the reasons why farmers make conscious decision to keep trees in their cultivated fields based on their indigenous knowledge of the useful roles that trees play in their livelihood by providing timber, fuelwood, food and medicine, livestock fodder, and shade for themselves and their livestock [Grandstaff *et al.* 1986; Vityakon 1993]. It has been further suggested by Dixon [1978] that an underlying reason for the retention of scattered trees in cultivated fields is the extensive nature of the Northeast agriculture. Farmers do not invest their limited labor time in totally clearing the land but instead concentrate on expanding the area under cultivation as long as there is more land available for opening up. This is due to the low productivity soils and unreliability of yields.

Mixed gardens (*suan* in Thai) are also a common land use in villages of the Northeast. Thomas [1988] defines this type of land use as mixed plantings of crops for household subsistence needs and for local trading. Traditional food crops include leafy vegetables, chillies, peppers, eggplants, several types of cucurbits and beans, bananas, papaya, and various fruit trees, herbs and spices; tobacco, betel, mulberry, cotton, kapok, leucaena and eucalyptus are common. The locations for the mixed gardens are upland areas of good fertility and moisture including house plots, separate plots inside the village settlement, banks of ponds, paddy fields after the rice harvest, termite mounds, and field hut plots.

The various land uses described above reflected the predominantly subsistence nature of Northeastern agriculture prior to World War II. However, the subsistence nature has gradually changed into more commercialized agriculture. Growing of rice for sale first began on a small scale during the 1920s and 1930s when railway lines were established [Dixon 1978] but increased considerably in the 1950s and after. Cultivation of upland cash crops, which started in the mid-1950s, has deepened the commercial nature of the Northeast agriculture. Table 1 summarizes some prominent events in the course of land-use change at the regional level.

Table 1 Some Prominent Events Related to Land-use Change Occurring during the Twentieth Century in the Northeast at the Regional Level

Year	Key Events and the Type of Economy
1830	The Northeast was brought under Thai administration.
	Subsistence-economy phase
1902–41	Evidence of existence of earthen dams for irrigated paddy rice.
1930	6.9% of total land was cultivated (synonymous with paddies which were mostly irrigated).
1920s–30s	Railway lines established leading to a small amount of commercial rice cultivation.
1930s–40s	Cattle raising prominent. There was an element of commercialization as some cattle were exported to Central Thailand.
1930–53	Shifting cultivation common but by 1953, only 3.5% of farm households still practiced shifting cultivation.
	Commercial-economy phase
1950s	Beginning of commercial upland cash crop cultivation. Rapid loss of forest.

Land-use change in the Northeast region can be attributed to the following factors:

1) Rapid population growth [Thomas 1988; Dixon 1978]. According to Thomas [1988] the population increased during the 65-year period (1920–85) from 3 million to 18 million people. As a result, farmers brought all usable land within existing villages under cultivation and then those who lacked land migrated to frontier areas to establish new settlements.
2) Expansion of the market and increasing commercialization of agriculture [Dixon 1978] arising from socio-political and economic changes at national and international levels. Since the mid-1950s cash crops have been grown increasingly in upland areas where productive paddy fields could not be established [*ibid.*]. As a result, the mixed gardens (*suan*) have been transformed into permanent upland fields [Thomas 1988]. The major upland cash crops grown in the Northeast have been kenaf, maize, sugarcane, peanuts and cassava. Changes in market prices have played an important role in determining the kind of upland crops farmers decide to grow at any particular time. Expansion of upland cropping has increased the area under cultivation and pushed the forest frontier further back.
3) Thai Government efforts to increase the extent of the Northeastern region's socio-economic integration into the Kingdom [*ibid.*]. This started in King Chulalongkorn's period during the nineteenth century in response to the threat of the French imperialism. It was followed by the enactment of National Socio-economic Plans under the administration of Field Marshall Sarit Thanarat in the 1950s and later under succeeding governments. The Northeast received increased attention from the central government partly as a mechanism to counter growing communist movements in the neighboring states. Since the 1950s, thousands of kilometres of strategic roads were constructed in the region. These roads have brought the Northeast villagers into market economy. A few large dams were constructed to provide electricity and irriga-

tion water and also accelerated regional development. Improvement of education and community developments were emphasized.

It can be concluded that land-use change at the regional level in the Northeast has been influenced by biophysical, socio-political and economic factors. All through the twentieth century, land use for subsistence rice growing received priority due to its being the staple food of the people. According to Thomas [*ibid.*] prior to the 1950s, farm holdings were probably considered to be virtually synonymous with paddy holdings. Wet rice was planted in the low-lying areas where water was easily available. Other crops for home consumption and, to a small extent, for sale locally, including cotton, tobacco, mulberry, vegetables, fruit trees and kenaf, were planted in mixed gardens and shifting cultivation fields in the uplands. Biophysical factors, e.g. terrain and crop characteristics, have played an important role in determining agricultural land use. Rapid population growth resulted in the expansion of the cultivated land of the villages. The forest frontier was pushed back as less suitable and more marginal land for wet rice cultivation was cleared. As the region has become more market-oriented due to changes in socio-political and economic factors, cash crops have become increasingly more important and the area devoted to their cultivation has increased further through clearing more forest land. Northeastern agriculture, therefore, possesses extensive characteristics as more land is cleared from forest to increase production as opposed to more intensive use of existing agricultural land to increase production per unit area.

IV Land-use Change at the Community Level

A closer look at land-use change in the Northeast can be taken at the community or village level. Four studies of land-use change in communities in different parts of the Northeast will be discussed, one study of villages in Kalasin province and three studies of different villages in Khon Kaen province.

IV–1 *Land-use Change in Villages in Kalasin Province*

Establishment of a new settlement is a key process bringing about land-use change in the Northeast. Dixon [1978], who studied villages established on relatively low-lying areas in Kalasin province in the central Northeast, equated the formation of a village with land clearance activities to establish paddy fields. He found that settlers first moved into and along the main river valleys taking advantage of the most fertile and reliable alluvial land, with good water supply and river transport. He divided the sequence of settlement into five stages:

In Stage I, the primary settlements were established on dry sites on the flood plain away from the most flood-prone land and adjacent to the lower terrace. The more flood-prone areas of the flood plain were frequently cleared first because of their high inherent fertility,

less dense vegetation, and fewer termite mounds. The relatively level land enabled small bunds to be constructed and large fields to be utilized for paddy cultivation.

In Stage II, after settlements were established, the relatively higher-lying land of the floodplain that is less fertile, more heavily forested, but also less flood-prone was cleared. In this stage, settlers moved out of the flood plain and onto the low terrace as the population grew, leaving some uncleared land which was important for grazing, hunting, and collecting forest products.

In Stage III of flood plain settlement, the utilization of dry sites near the rivers and the cultivation of fertile but highly flood-prone land occurred.

In Stage IV, as population continued to grow, the higher and less fertile area of the lower terrace and, later, parts of the upper terrace were cultivated. These areas are less fertile and more vulnerable to environmental hazards, particularly drought. The movement into more marginal areas resulted in increases in the average size of holdings to compensate for the lower yields and as an insurance against crop loss from environmental hazards.

In Stage V the cultivation of upland cash crops, notably kenaf, maize, and cassava, began in the 1950s on land that would have been marginal for paddy. At this stage permanently cultivated upland fields are developed on middle and high terraces. Agriculture became more extensive as more land is cleared for cultivation as a result of population increase and low productivity of land. Once a settlement (village) reached its full capacity in terms of resources available for settlers (one indicator of this is the distance from the village to uncleared land which new settlers could take up), excess people had to migrate to uncleared land elsewhere and form a new settlement [*ibid.*].

IV–2 *Land-use Change in a Village in Undulating Terrain in Khon Kaen Province*

Another study of a village which was established in 1867 in an undulating terrain in Khon Kaen province in 1867 [Subhadhira *et al.* 1988] identifies four stages in land-use change and also presents an analysis of the impact of external forces on the village and the consequent changes in agroecosystem properties. Initially only the low-lying parts of the undulating terrain were cleared for cultivation but gradually, cultivation expanded into upper-lying areas as a result of population increase and cash crop cultivation.

During Stage I of village development (1867–1938), land use was mainly wet rice fields in low-lying areas, mixed gardens in relatively upper-lying areas, livestock grazing in uncultivated upper-lying areas, and forest in the uppermost part which provided various products for villagers' livelihoods. Although most activities were for subsistence purposes, there was a commercial element in selling of cattle to the Central region. This was one of the two external forces influencing the village in this phase. The other force was the in-migration of people from other areas in the Northeast. The village is considered to have high self-reliance, and autonomy and satisfactory productivity at this stage.

In Stage II (1938–60), the village saw an increase in population due mainly to in-migrations which continued until 1943. The population increase resulted in a decrease in the land-

to-people ratio. This led to emigration to find more cultivated land leading to the formation of a new settlement close-by. Commercialized agriculture increased as seen by exporting of glutinous rice to other Northeast provinces using carts and river transport, a short period of cotton trading to the Central region during World War II, and expansion of kenaf cultivation as cash crop beginning in the 1950s. These activities resulted in expansion of cultivated land through further clearing of the forest. The decrease in the area of forest land resulted in decreasing nutrient availability and soil organic matter in the fields and a decline in the supply of natural foods and other products obtained from the forest within the village system. Forest products were replaced by some importation of consumer goods and foods. The village at this stage became less subsistence oriented and more influenced by external forces related to market economy. Its self-reliance became lower. In addition, its autonomy also decreased due to the central government's intervention in village affairs.

In Stage III (1960–79), the village became more accessible due to road construction and was more influenced by more external forces than in the past. In addition, its relationships with outside forces moved up the hierarchical level from provinces within the Northeast to the Central region and the world market. There was an expansion of kenaf cultivation as a cash crop into the forested area in the northern part of the village. The number of livestock decreased due partly to reduced availability of grazing land in the forest. Kenaf was the major cash crop grown for export but some non-glutinous rice was also grown as a cash crop. During this period, cassava was introduced as another cash crop. The cultivation pattern in permanent upland fields became increasingly monocultural as the more diversified mixed gardens were gradually replaced. Rapid expansion of cultivated areas into the forest was seen in this phase. Rice cultivation was expanded into upper-lying areas which resulted in constructions of earthen weirs and ponds to supply water for rice cultivation. Chemical fertilizers began to be applied at this stage to maintain productivity which otherwise would have been low due to nutrient depletion in the system.

In Stage IV (1979–84), continued expansion of cash crops occurred. A new cash crop, i.e. vegetables for seed production, was introduced in low-lying areas. This required high input of labour, chemical fertilizers and pesticides. Moreover, more ponds were constructed for fish raising as natural fish became scarcer. At this stage, villages became more dependent on external resources for even such basic necessities as food and agricultural inputs (chemical fertilizers, pesticides).

From Stage I to IV, the village experienced decreasing self-reliance and growing loss of autonomy. Productivity was maintained or increased by relying on external resources, such as chemical fertilizers.

IV–3 *Land-use Change in a Village in Undulating Terrain with a Prominent Floodplain in Khon Kaen Province*

A very detailed agroecological study of a village in Khon Kaen province was conducted by an interdisciplinary Japanese-Thai team in 1981 and 1983 [Fukui 1993]. The settlement was

established sometime before 1871 when it was officially recognized as a village by the government. The settlement was situated at the edge of high ground of the typical Northeast undulating terrain overlooking the floodplain of the Chi River where most of the paddy fields were established. The rest of the paddy fields were in the upper-lying areas intermediate to the uplands. Paddy fields were the first agricultural land use practiced by the early immigrants. They first opened up lands in depressions (*nong* in Thai) of the undulating terrain but left aside the bottom lands that had poor drainage for later conversion. Almost all of the lower parts of the depressions had been developed by the mid-1930s and accounted for slightly over half of the paddy area in the 1980s. The expansion of paddy areas from lower parts towards the edge of the depressions began in the 1940s in response to population growth. This expansion took a much shorter period than that of the low-lying paddy fields during late the 1930s and the 1940s. The expansion was into less productive land but since this new upper-lying land was a supplement to the older more productive paddy fields all households reclaiming land owned both types of paddy fields. Fukui [*ibid.*] was reluctant to call this process of combining the less productive newly-acquired land with the old more productive paddy field, *expansion of arable land*, and he opted to call it *expansion of supplementary arable land*.

Fukui [*ibid.*] has related changes in the village land use to changes in its population that occurred in three stages. In Stage I the process of village development consisted of in-migration of people from near-by areas, approximately 60–100 kilometers away. The founding population of the village was 50 people. Studies on demographic history of the village since 1900 have shown that during the initial stage of village development (1900–19), in-migration was predominant. In Stage II (1920–34), in-migration and out-migration balanced; and in Stage III (1935–83), out-migration was predominant.

The main reason for in-migration in Stage I was "land pioneering" to find new land for paddy rice cultivation. This generally involved movement of entire households. The land-use activity during Stage I was the opening up of land in the lower parts of the depressions to establish paddy fields. This had been practiced as early as late nineteenth century by each group of early immigrants who were mainly groups of kinspeople from the same place of origin. The last large group of immigrants to have settled in the village arrived in 1916 [*ibid.* : 60]. Each group came to occupy its own *nong*.

In Stage II, the opening up of the new land in lower parts of the depressions continued until the supply was exhausted after which the clearance of upper-lying fields began. At the end of this period, population outflow took place concurrently with the opening up of the less productive new paddy land. Emigration at this stage was mainly in order to find new land for paddy fields (land pioneering) as population pressure began to be felt. In the first 40 years of Stage III (1935–74), emigration for purposes of land pioneering intensified leading to the formation of a new settlement that became a "daughter" village.

Upland cash crop cultivation was started on a small scale in the village during WWII when cotton was planted in response to demand created by a sudden reduction in raw cotton

imports. Since the village was situated in the floodplain topography, however, the upland area was much smaller than the area of paddy land. In the 1980s the ratio of area occupied by paddy land to that of upland was 100:19 [*ibid.* : 56]. Cotton was cultivated by slash-and-burn method on upper-lying land cleared from the existing sparse forest and scrub. A plot was cultivated only once before it was abandoned. The practice was short-lived as a result of the end of the wartime boom. Major upland crop cultivation started in the mid-1950s with kenaf and was followed by cassava in the 1960s. Both crops were aimed at the export market. Kenaf was initially cultivated on the abandoned cotton swiddens. It was reported that its cultivation led to the first recognition of the ownership of the upland fields [*ibid.*]. The cultivation of these cash crops led to major deforestation in the upland area of the village so that by the late 1960s almost all the wooded land around the village that had remained in the mid-1950s had disappeared.

IV–4 *Land-use Change in Kham Muang Village*

The village of Kham Muang was selected in 1997 as the study site of our project on "Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand." The village-level study employed a semi-structured interview technique as described earlier in the Methodology section.

Kham Muang village (Ban Kham Muang) is situated approximately 45 kilometers north of Khon Kaen city and 6 kilometers from the municipality of Khow Suan Kwang (Fig. 2) and is conveniently accessible by a concrete road.

Kham Muang village is situated in deeply undulating terrain typical of the topography of

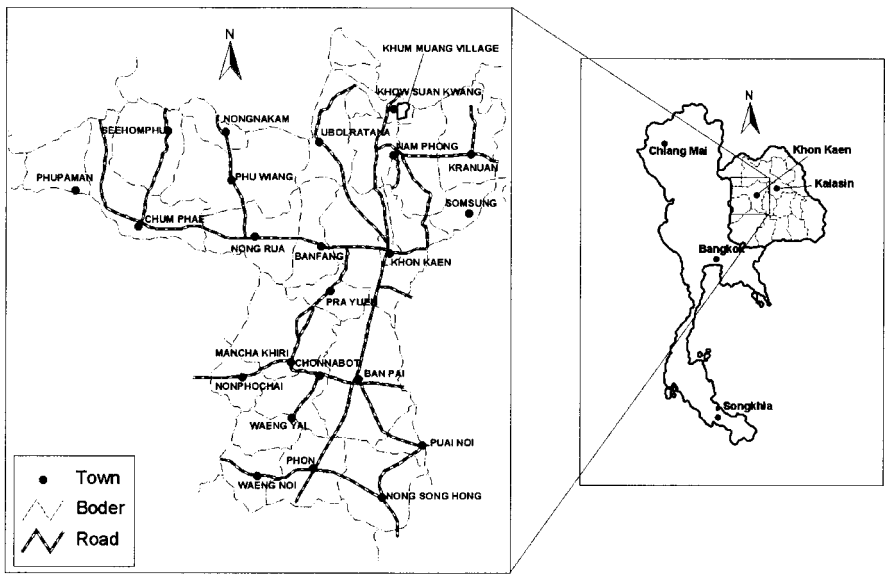

Fig. 2 Location of Kham Muang Village

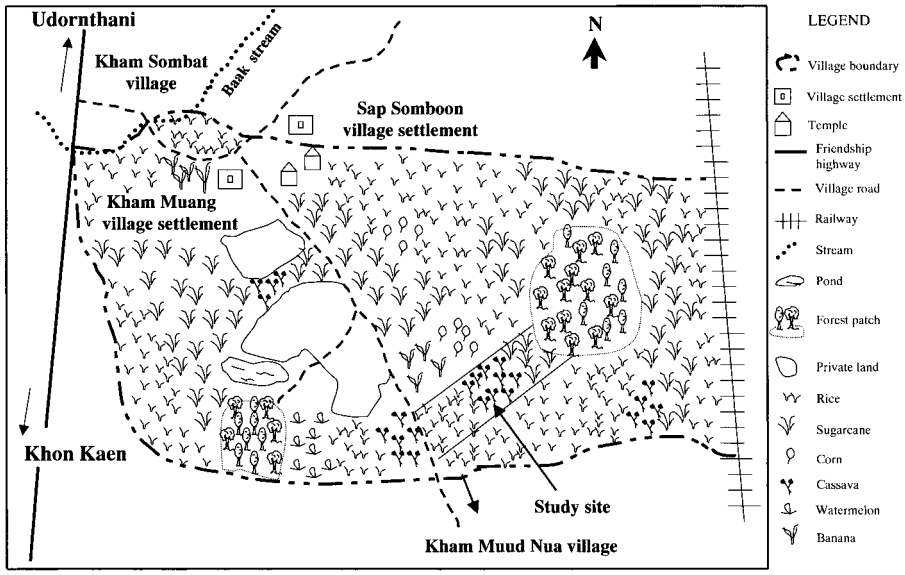

Fig. 3 Boundaries and Land Use in Kham Muang Village in 1998

the Khorat basin. It has an area of 3,600 *rai* (576 hectare, 1 ha = 6.25 *rai*). The settlement is situated on upper-lying area overlooking paddy fields on adjacent lower-lying area to the west. The settlement occupies 475 *rai* (76 hectare) or 13.2% of total land area. Agricultural lands occupy 2,500 *rai* (400 hectare) or 69% of total land area. They were located to the east and west of the settlement (Fig. 3). The eastern part is deeply undulating while the western part is relatively flat lowland. The ratio of area of upland fields to lowland paddy fields is 3 : 2. Public lands, mainly the cemetery and reserved land (forest), occupy 529 *rai* (84.6 hectares) or 15% of total village land. The average household land holding is 18 *rai* (2.9 hectares). There were 5 landless households out of the total number of households of 137.

Kham Muang village was founded approximately in 1889. The first group of people who settled in the area was composed of livestock merchants-herdsmen and their families from Roi Et province to the southeast. In the course of their searching to buy livestock, they found an upland area covered with lush forest vegetation with springs from shallow ground-water which appeared to be available all year round. This was considered a good place for a new settlement, which they named Ban Kham Muang (Ban in Thai means a community) because of the presence of numerous native mango trees (*mak muang* in Thai) in the area. More than 10 years after the first group of pioneers arrived, several other groups came to settle including those from Nam Phong and Kranuan districts of Khon Kaen province, and Kosum Phisai district of Maha Sarakham province.

The original settlement was situated on the edge of the upper-lying area overlooking a low-lying area. However, after a disease epidemic, the village was moved to its present site which is nearby the original one.

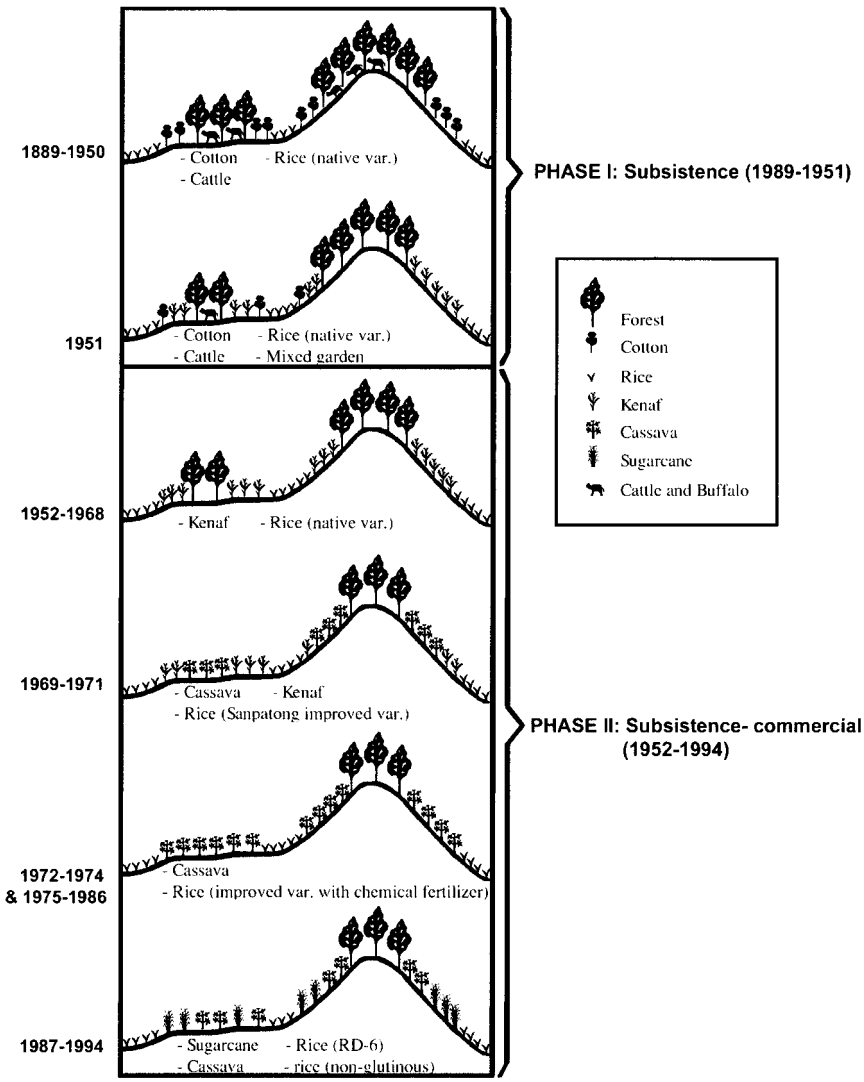

Fig. 4　Stages of Land-use Change in Kham Muang Village

The pattern of land-use change in Kham Muang village from its formation is broadly similar to that of the other villages in the Northeast that have already been described. Based on information from key-informant interviews, such changes from 1889 can be divided into three stages (Fig. 4) as follows:

IV–4–1 *Stage I (1889–1951): Subsistence Stage*

Land use by villagers during this stage was mainly for subsistence purposes. The land area can be divided into three zones according to the land use as related to the terrain (Fig. 3).

The first zone was low-lying areas found in the depression of the undulating terrain initially along the Huay Baak (Baak stream) to the southwest and northwest of the present settlement. Huay Baak was the major drainage channel of the village. Villagers opened up this land to grow native glutinous varieties of paddy rice for home consumption. After all the land around Huay Baak was used, low-lying areas in the depressions to the east of the settlement were opened up for paddy rice. The second zone was the upland part of the undulating terrain where some field crops were grown for subsistence. The most important field crop during the early period of settlement formation was cotton, the fiber of which was used for cloth weaving. The third zone was the undisturbed upper part of the undulating land near the village that was covered with forest. The forest zone was used to raise buffaloes and cattle. The forest also provided natural foods, fuel, timber and medicinal plants for the villagers. Another type of land use in this period was mixed garden found in various zones but mainly on the upper grounds of the paddy field areas. The grown crops included native melons, tobacco, and sugarcane for home-made sugar. Cotton was also grown on termite mounds in paddy fields in the form of mixed garden.

As population grew, there was expansion of the paddy fields from the lower parts of the depression onto relatively higher areas on the edge of the depression or towards the upland. This area is marginal for paddy rice from the standpoint of soil fertility and water availability as compared to the area in the lower part of the depression.

In this stage, crop production was guided by indigenous knowledge. Soil fertility was sustained by natural fertilizers in the form of weeds, crop residues, animal manure, and leaves and debris from the forest. Cropping patterns that maintained soil fertility were practiced, such as crops rotated with fallow periods. Land preparation and transport were performed by draught animals and human labor.

IV–4–2 *Stage II (1952–94): Subsistence-commercial Stage*

This period can be divided further into three sub-periods based on the introduction and spread of major commercial crops and the increasing degree of adoption of high-input agriculture, i.e. Stage IIa (1952–68), Stage IIb (1969–86), and Stage IIc (1987–94).

During Stage II, land use in agriculture changed from having a full subsistence-orientation to being semi-commercialized as a result of road construction starting in the mid-1940s that brought the village into more contact with the outside world. During this stage paddy rice was planted in the low-lying areas and some parts of the upper-lying areas. It was mostly raised for home consumption but any surplus was sold. In the Stage IIa (1952–68), growing of cotton in the upland area was gradually replaced by kenaf. Kenaf was first introduced in 1952 when the villagers started to grow kenaf on a small area (less than 1 *rai*). However, the growing area gradually increased. In 1968, an agricultural produce enterprise in Khon Kaen city promoted kenaf planting by providing seeds and buying the produce. Kenaf cultivation led to greater forest clearing.

Stage IIb (1969–86) saw greatly increased village involvement in commercial and high

input agriculture. In 1969, a new cash crop, cassava, was introduced by a pioneer grower in the village who brought it in from the outside. It gradually replaced kenaf as the main cash crop. By 1973–74 kenaf cultivation had declined dramatically due to rapid expansion of cassava. Cassava was the dominant cash crop until 1986 and its cultivation led to further forest clearing. In addition, a new improved glutinous variety of rice, Sanpatong, was introduced in 1971 to replace the native varieties. In 1977, chemical fertilizer was introduced by the agricultural extension office. The fertilizer formula was initially 16–20–0, later it was changed to 15–15–15. It was initially applied to paddy rice at low rates (approximately 10 kg per *rai*) which is 2.5 times less than the present rate.

In the Stage IIc (1987–94), even more commercialized and high input agriculture was adopted. In 1987, another new improved glutinous rice variety, RD 6, was introduced by the local agricultural office. It gradually replaced all the native varieties in subsequent years. Around this time non-glutinous rice began to be cultivated in the village. The variety was aromatic Khao Dok Mali 105 or jasmine rice. Its adoption reflected the changing cultural values of the villagers as members of the younger generation, who, as a result of their exposure to external influences through schooling and travel outside of the village, tended to adopt non-glutinous rice for their diet. The non-glutinous rice was also grown for sale. During the same year, sugarcane was planted in the village in response to the market created by the construction of a sugar refinery in nearby Nam Phong district. During this stage, cassava and sugarcane were about equally dominant on the uplands. Choice between growing each of the two crops was determined by market prices of the crops, size of land holding, and capital input. The continuous growing of upland crops led to soil degradation as indicated by yield decline. Starting in 1994, 15–15–15 combined chemical fertilizer had to be applied to cassava at the rate of 50 kg per *rai*. One way to alleviate yield decline in cassava was to rotate it with sugarcane because the residual fertilizers from previous crops of sugarcane and its organic residues, especially from sugarcane roots, brought about an increased yields in the subsequent cassava crop.

Encroachment of both cassava and sugarcane led to a decrease in the forest area of the village. By approximately 1987, the village forest area of 2,000 *rai* was reduced to approximately 400 *rai*. This prompted the village administrators to institute conservation measures. As a consequence of the forest decline, the number of buffaloes and cattle gradually decreased due partly to the lessened availability of forest and vacant uplands for grazing.

In Stage II high-input technologies for agriculture were increasingly adopted as a consequence of the shift from subsistence to more commercialized agriculture. These high-input technologies included the new improved varieties of rice, chemical fertilizers, and two-wheel hand tractor for ploughing. These tractors replaced draught animals contributing to a further decrease in the number of buffaloes and cattle and thus a reduced supply of organic manure in the village.

IV–4–3 *Stage III (1995–97): Removal of Land from Agricultural Use to Construct a Private Housing Project*

In 1995, the upland agricultural area was reduced by the sale of a parcel to land speculators who intended to convert it into a commercial private housing project. However, the progress of this type of land use was hampered by the economic crisis beginning in 1997 so the land was left idle. In the future, however, when economic growth resumes in the Northeast, more land may be taken out of production for housing and industrial uses.

IV–5 *Some Common Characteristics of Land-use Change at the Village Level in the Northeast*

It can be seen from the various village studies presented above that biophysical, demographic, economic, and sociocultural factors all influenced the process of land use change. In all cases selection of land to develop at the founding of a settlement was decided initially on biophysical grounds, i.e. the most productive land was invariably selected first. With subsequent population growth, more peripheral, less productive land was brought into use. This has been found to be a common pattern [Fukui 1993: 309]. Our studies in Kham Muang village provide results that substantiate the above statements. It was found that paddy fields were established first in the fertile lowland with alluvial soil along the major stream channel of the village. Later after the best land was used up, the less productive land in the low-lying areas but away from the major stream was brought into use. As population grew, there was expansion of the paddy fields from the lowlands into relatively higher areas. Economic factor, notably the change from subsistence to partial market economy, was a major influence on land-use change in all villages. In Kham Muang village, starting in the mid-1940s there was some road construction that brought the village into more contact with the outside world. By the early 1950s kenaf as a cash crop began to replace cotton. Kenaf could be sold to some local commercial enterprise. The prominent socio-cultural characteristic resulting in the land-use change at the village level is “the land pioneering” habit of the people which led to establishment of new settlements in areas still covered by forest. Settlement establishment is characterized by land clearance. The sequence of settlement described by Dixon [1978] and illustrated by examples of subsequent work by other researchers, gives rise to clustered nature and, as described by Sternstein [1965], spatially even distribution of settlements in the Northeast.

V Land-use Change at the Landscape (Mini-watershed) Level: A Case Study at Hom Bak Heb Mini-watershed

A “mini-watershed” in the undulating terrain was selected as a representative unit of land use for the study of land-use change at the landscape level. The site is located in the southeast part of the Kham Muang village, 2.5 km from the settlement (Fig. 3). It is situated between the latitude of 16˚48'–16˚49' north and the longitude of 102˚52'–102˚53' east. The

mini-watershed is located in an area locally known as Hom Bak Heb.

V–1 *Area and Boundaries*

The total area of the mini-watershed is 88 *rai* (14 hectares). The longest part was in the north-south direction which was 600 m, while the widest part in the east-west direction was approximately 250 m (Fig. 5a). The northeast boundary was a forest reserve. The southern boundary is a dirt road connecting Kham Muang village with a neighbouring, Kham Muud Nua village. The eastern and western boundaries are cultivated land of Kham Muang village (Fig. 3).

V–2 *Landform, Geology and Soils*

The name *hom* in the Northeastern language indicates a depression or a kind of landform that resembles a saddle or a small valley consisting of the bottom part and the upper-lying part located on the upper slope. This kind of landform is considered a mini-watershed as the water flows from ridges at the topslopes which form the watershed boundaries down to the bottom part (Fig. 5b). There used to be a stream running in the low-lying part of the mini-watershed before it was transformed into paddy fields. Hom Bak Heb mini-watershed has gently undulating terrain with an average slope of 2.8% in the north-south direction. The elevation at the lowest part is 190 m above sea level (asl) and 208 m asl. at the uppermost point in the forest reserve (Fig. 5a, b).

Geologically, it consists of a layer of bedrocks situated at a 10–12 m depth below the soil surface (information from seismographic study). The bedrock is laid out in an almost parallel fashion to the surface topography. Most of the rock is sandstone with some shale inclusion. The rock belongs to the Khok Kruat formation (Kkk) which was formed during Cretaceous geological period (Groundwater map of Khon Kaen province, Dept. of Mineral Resources). Information on surface lithological compositions down to 8 m obtained through drilling of 9 bore holes showed that it has sandy to sandy loam textured soil down to 0.8 –1.30 m below which it became clay. There are layers of laterite and materials of gravel size below the clay layer.

Soil profile studies showed that the soils were derived from alluvial parent matrials of sandstone origin. In general, the soils have a coarse texture (loamy sand to sandy loam for the upland soils and sandy clay loam for the lowland paddy soils). Where there is no clay accumulation at approximately 1 m depth, they were considered Great Group Quartzipsamment (Soil Taxonomy system of soil classification), however, if there is a horizon of clay they belong to the Great Group Paleustult. They were three soil series found. The paddy soil belongs to the Ubon series (Aquic Quartzipsamment) and the upland soils belong to the Khorat series and Satuk series (Oxic Paleustults). An interview with a farmer-owner of part of the land in the mini-watershed revealed that he classified the soils in the mini-watershed into three types: black soil (mainly in the bottom of the lowlands), sandy soil (the most dominant in the mini-watershed) and stony soil (low coverage—approx. 10%). It can be seen that

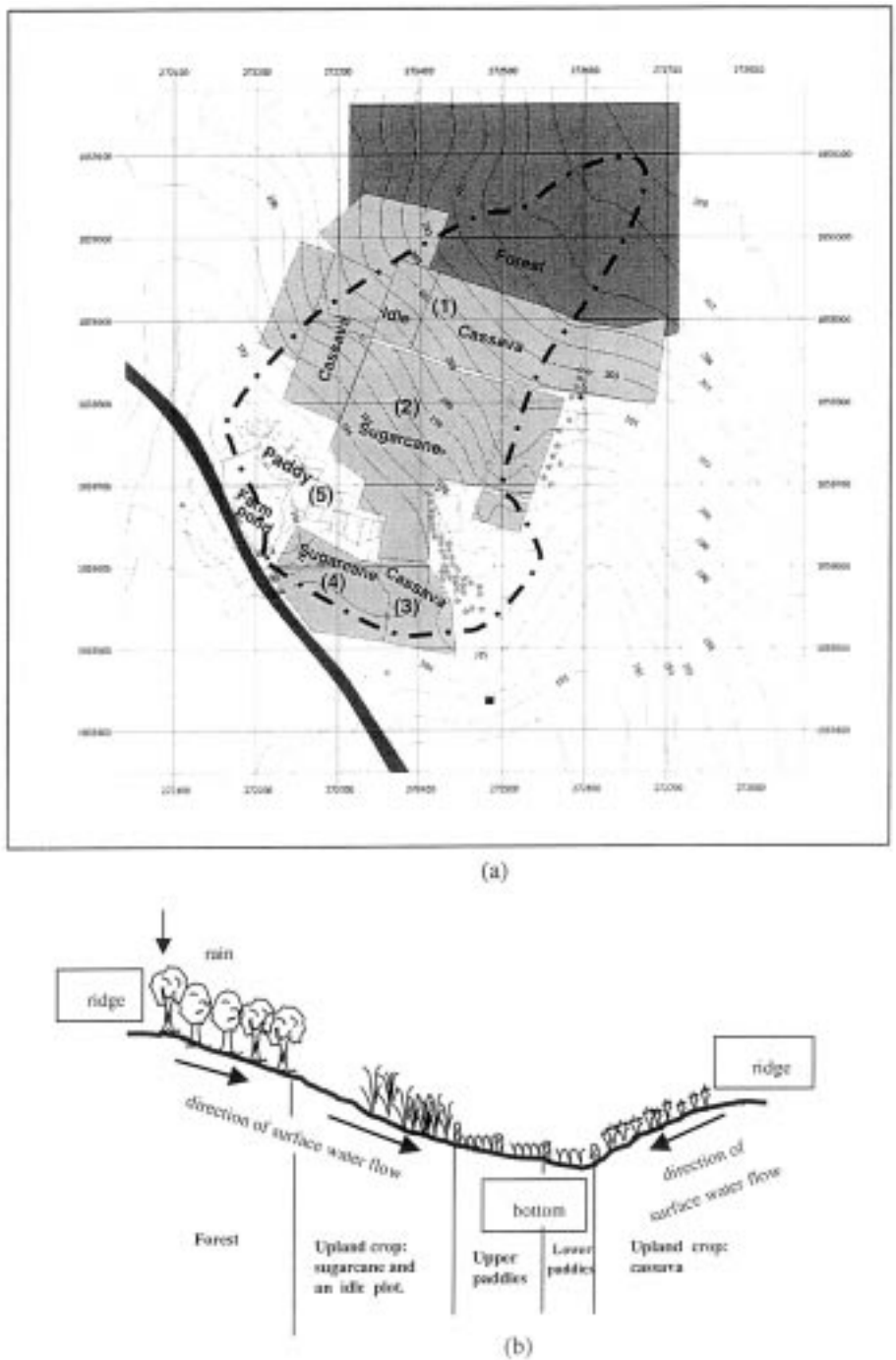

Fig. 5 The Mini-watershed: Boundaries (Thick Broken Line), Contour Lines (Thin Solid Lines) and Land-use Plots of Different Kin Farmers (Indicated by Number in Bracket) in 1998: (a) Top View, and (b) Cross Sectional View

the farmer used texture and color as two prominent criteria to classify the soils. This farmer classification matches with the scientific one most closely from the viewpoint of soil texture. Sandy soils, notably topsoils, predominate in the mini-watershed. However, the color criterion, i.e. black soil, was not used in the scientific classification. This is likely because the black materials are some finer-than-sand materials consisting of some silt and clay with organic matter that form a thin layer on top of coarser materials. These materials are washed from the higher grounds and deposited in the lowlands. This does not influence the scientific classification.

V–3 *Land Use and Land-use Change*

Land use in Hom Bak Heb mini-watershed in 1998 consisted of forest and agriculture. A patch of forest remained in the northernmost part of the mini-watershed. It was a part of the 400-*rai* reserved forest of the subdistrict. It was dry dipterocarp forest commonly found in the undulating terrain. The dominant species was *Dipterocarpus tuberculatus* (*pluang* in Thai).

Agricultural land use in Hom Bak Heb mini-watershed at the time of the study (1998) involved five households. Three of these households were related through kinship, i.e. plot 1 was used by Mr. Bunmee, the eldest son-in-law to the legal owner (Mrs. Suk); plots 2 and 4 by Mr. Kong, her young son-in-law; and plots 3 and 5 by Mr. San, her youngest son (Fig. 5a). Interviews with some farmer-land-owners revealed the history of the land use in the mini-watershed from the time of their ownership. The present land owner (Mrs. Suk and her husband) bought the land in Hom Bak Heb from a previous land owner in 1960. The land in Hom Bak Heb had earlier been under forest. At the time of the land-ownership change, the lower part of the land, including the bottom and the lower part of the upland, had been opened up for agriculture by the previous owner, however the forest in the upper part was still relatively intact. Forest clearance occurred from the lower parts upward. The lower-lying area adjacent to the southwest border of the watershed was cleared first for paddy field construction followed by the lower parts of the upland fields (e.g. plots no. 2–4 in Fig. 5a). This definitely occurred before the land sale in 1960 and may have occurred in the early 1950s as the previous owner had cultivated kenaf prior to the selling of the land and it is known that kenaf was first cultivated in the village in 1952 (Fig. 4). Kenaf was cultivated by the family in plot no. 2 (Fig. 5a) for 14 years until 1974 after which cassava was cultivated continuously until 1987 when sugarcane was introduced.

The upper-lying part of the upland in Hom Bak Heb (plot no. 1 in Fig. 5a) was cleared in 1969 when the family acquired a new son-in-law by the marriage of the eldest daughter. The land was cleared by the eldest son-in-law for kenaf cultivation. By the early 1970s kenaf was replaced by cassava.

Land use was extensive rather than intensive as the result of new land being brought under cultivation in upper-lying areas of Hom Bak Heb watershed. Cash crop cultivation alternated with periods of fallow in the early stage as long as there was new land available

for opening up. The planting of upland crops in the newly-cleared land signified the intention to own the land.

Sugarcane was introduced in 1987 but did not replace cassava in the same way the latter did with kenaf. Both crops became major cash crops and were grown in Hom Bak Heb mostly alternately in a 2-year cycle; however crop price is a major factor determining whether farmers opt to plant cassava or sugarcane at any particular time. The alternate pattern of growing sugarcane and cassava is also done to help maintain crop yields through rotation. It was found that cassava grown after sugarcane produced better yields than continuous cassava because the residual chemical fertilizers from sugarcane and the organic residues left behind after the cane is harvested improved the fertility of the soil. Crop prices, however, are a more important factor in determining the kind of cash crops to be grown. Watermelon was another cash crop grown in rotation with cassava and sugarcane in the mid-1990s. It required relatively high inputs of fertilizers and pesticides. However, watermelon was abandoned due to the health hazard to the growers caused by the pesticides used.

The paddy fields at the low-lying part of the mini-watershed were planted totally to the RD6 glutinous rice for home consumption at the time of the study (1998). In 1992, the bottom part of the depression was turned into a farm pond for fish raising for consumption.

VI Effects of Land-use Change on Biophysical Characteristics at the Landscape and Plot Levels

Biophysical studies conducted at the plot and landscape levels (under our project "Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand"—LDP) have revealed that land-use change has brought about land degradation notably in the upper-lying part of the mini-watershed, while the lowland paddy fields are not considered degraded. The indicators used to show land quality changes were comparative soil erosion and soil organic matter characteristics under the forest (the original land use) and agricultural field plots. Soil erosion was significantly higher in the upland field crops system than the forest system, for example in the year 2000, soil loss in the forest plot was 1.8 t/ ha/yr while the loss in the cassava and sugarcane fields was approximately 20 t/ha/yr (LDP, unpublished data). The upland field crop erosion value was well beyond the soil loss tolerance value of the US Soil Conservation Service of 10–12 t/ha/yr. Nitrogen (N), phosphorus (P) and potassium (K) losses through erosion in the same year were also much higher in the field crop plots than in the forest, i.e. (in kg/ha of nutrients) in the cassava plot: 15.5 N, 3.2 P and 7.1 K; in the sugarcane plot: 8.2 N, 1.2 P and 3.3 K; and in the forest plot: 1.5 N, 0.2 P, and 0.6 K. The high loss in field crop plots results from their low percentage of ground contact cover and frequent soil disturbance, such as from ploughing, especially during heavy rains. The forest plot had better developed ground cover and the

surface was relatively undisturbed.

An interview with a farmer cultivator of part of the land in Hom Bak Heb revealed that he perceived soil erosion as severe. However, the farmer perceived soil erosion to be a problem only because poor quality soil from the upper areas moved downslope to cover better quality soil in lower-lying areas. The phenomenon of soil movement was considered a prominent process that had been occurring in the mini-watershed since the early days of land transformation from the forest. The farmer categorized the soils in the mini-watershed into three types: sandy soil (*din sai*), black soil (*din dum*), and lateritic soil (*din hin kon sao*). Lateritic soil only occupies 10% of the total land area. Black soil, found in low-lying areas, is more fertile than the other two soils. In the past when there was more forest, black soil covered most of the farmer's fields, but it had been steadily decreasing to 20–30%. The decrease was perceived to be due to the flow of sandy soil eroded from the higher areas and mixed with the black soils in the lower areas including paddies. Paddy soil was also black but it had been becoming mixed with sandy soils as a result of sedimentation. The farmer indicated that when there was more forest, there was no flow of sandy soil into other areas.

Another indicator of land degradation used in our study was soil organic matter (SOM). In our study, the SOM of the whole soil, i.e. total soil carbon and nitrogen, and those of fractionated soils (different SOM pools: labile and stable) were investigated in various land-use plots in the mini-watershed [Tangtrakarnpong and Vityakon 2002]. Labile pools, such as microbial biomass, are those that are transformed rapidly, while the stable pools, such as humic substances, are the slowly-transformed part. The study showed that the contents of various pools were higher in the forest than in the upland field crop systems (cassava and sugarcane). However, the rice paddy system had some SOM pools comparable to those of the forest (Table 2). Again the SOM results indicated that the upland field crop systems were degraded relative to the forest. The paddy system was not degraded as far as SOM

Table 2 Soil Organic Pools and Mineral Nitrogen in Soils under Different Land Uses in Hom Bak Heb Mini-watershed

Land Use	Total Carbon	Total Nitrogen	Microbial Biomass Carbon	Microbial Biomass Nitrogen	Litter (> 2 mm size) Carbon	Particulate Organic Matter (1–2 mm) Carbon	Humic Acid Carbon	Mineral Nitrogen
			g kg^{-1} soil					mg kg^{-1}
Forest	5.5 a[1)]	0.30 a	116.1 a	26.6 a	1.13 a	0.40 b	2.93 a	0.75 c
Paddies	4.2 b	0.30 a	78.3 b	29.9 a	1.17 a	1.07 a	2.39 b	2.47 b
Cassava 1	1.2 d	0.05 d	37.2 c	7.1 c	0.20 bc	0.15 b	1.14 d	2.89 b
Cassava 2	1.2 d	0.09 cd	33.5 c	8.0 c	0.15 c	0.17 b	1.25 d	2.34 b
Sugarcane (ratoon)	2.0 c	0.11 bc	78.2 b	17.5 b	0.78 ab	0.14 b	1.82 c	2.71 b
Sugarcane (planted)	4.0 b	0.18 b	75.5 c	16.5 b	0.85 a	0.64 b	1.51 cd	15.37 a

Sources: Adapted from Tangtrakarnpong and Vityakon [2002] and Tangtrakarnpong [2002]

[1)] Means in the same column followed by similar letters are not significantly different at 95% level of probability (LSD).

indicators revealed. This was likely due to the heavier texture of the paddy soil relative to the upland soils, and the location of the paddies in the low-lying area that was conducive to deposition of materials from the upper-lying parts of the landscape.

Contrary to the SOM results, the mineral N content was lower in the forest than the cultivated fields (Table 2). This shows that the forest system has a higher efficiency of nitrogen cycling than the agricultural systems. Mineral N produced from decomposition of *in situ*-derived organic matter is taken up rapidly by diverse organisms including plants and microorganisms, while little N is input from external sources. On the other hand, the agricultural systems, notably the sugarcane (planted), received higher N input from various external sources, especially from fertilizers. Timing and placement of the fertilizers were likely not precise. This coupled with unsynchronized nutrient requirements of soil microorganisms led to some excess fertilizers remaining in the soil.

These plot-level and partly landscape-level studies suggest that ecosystems with a tree component tend to retard land degradation. The Northeast landscape is tree-studded. There are still trees left at different densities in cultivated fields. Trees in fields are discussed in many research articles, for example Vityakon [2001]; Grandstaff *et al.* [1986]; Watanabe *et al.* [1990], and Takaya and Tomosugi [1972]. This form of indigenous agroforestry has potential for further development aimed at increasing the number of trees in cultivated fields to counter land degradation.

VII Conclusions

VII–1 *Inter-relations among Land-use Changes at Different Scales*

This analysis of land-use change in Northeast Thailand during the past century at four different socio-ecological scales has revealed that changes at all levels have been in a similar direction: the land was transformed from forest to cultivated fields by pioneering farmers. In the earlier subsistence stage land transformation did not lead to dramatic forest loss at any scale. It was only after the region as a whole had entered into the market economy and cash crops were being increasingly cultivated within the communities starting in 1950s that the transformation of forest to cultivated land was rapid.

At the community and landscape levels land transformation began first in the lowlands and worked its way upward to the uplands. The lowland was changed into paddy fields producing rice for subsistence. This pattern was similar in communities situated in both the undulating and the prominently floodplain landforms. The manner of land transformation reflects the influence of biophysical factors, notably terrain, soils and crops to be grown. The lowland areas usually have high fertility soils and flat terrain that facilitates building of large paddy fields. Consequently, irrigated paddy rice was dominant in the region during the first half of the twentieth century [Fukui *et al.* 2000]. This is in agreement with the data at the community level on the prominence of lowland paddy fields that could make use of

irrigation water diverted from streams by dams or weirs.

The use of the uplands was also originally for subsistence, such as growing of cotton and sugarcane for home consumption. However, as population increased, paddy fields were expanded into more marginal land on the higher grounds, although these upper paddies were less productive than those in lower-lying areas. During the 1950s, cash crop cultivation in the uplands started. The first crop was kenaf, followed later by cassava and sugarcane. In this regards, the information at different scales, i.e. regional, community and landscape, agrees with each other.

VII–2 *Factors Affecting Land-use Change*

Analysis employing data from both the regional and community levels has shown that at the earlier stage population growth was the leading factor bringing about land-use change from forest to agriculture. Increasing population led to a lower land-to-people ratio and a consequent reduction in land resources available to support livelihoods. Within communities a cultural factor joined forces with population growth in causing out-migration of people to find new land for paddy rice cultivation in a process termed “land pioneering” [Fukui 1993]. At a later stage after the population had grown, the change in the economic orientation of agriculture from subsistence to commercial appears to be the major factor of land-use change at both the regional and the community levels. This economic change was accompanied by many other changes, such as building of infrastructure (good roads, dams and schools etc.), beginning of cash crop growing in the uplands, and the development of agroindustries which required inputs of agricultural products, notably sugar production. In addition, the Northeast was affected more by external factors at both regional and community levels. The external factors came from national and international level. At the regional level, government policies (socio-political factor) favored greater integration of the Northeast into the country as a whole.

VII–3 *Present Conditions of the Land*

The change in land-use from forest to agriculture has brought about changes in land conditions. Degradation characterizes the condition of the upland fields due to erosion, loss of soil nutrients and organic matter. This degradation is associated with the monocultural nature of the upland cultivation that requires applications of fertilizer at higher rates to maintain crop productivity. On the other hand, paddy fields, especially the lower paddies, although under cultivation for longer times than the uplands, still maintain their relatively non-degraded conditions. However, their status depends on their interactions with the uplands since they receive deposits of nutrients and organic materials eroded from the uplands. It is known, for example, that the potassium economy in paddy fields situated in undulating terrain in the Northeast depends in part on K in surface runoff and subsurface water flowing from the uplands [Vityakon 1989]. Thus it can be said that the degradation process in the uplands contributes to the aggradation of the lowlands. It appears that the

upland-lowland interactions play important roles in the sustainability of the mini-watershed agroecosystem of the undulating terrain. More landscape level studies are needed to better understand these upland-lowland interactions.

The presence of trees in cultivated fields at the plot scale, and as patches of remnants of forest interspersed with cultivated fields at the landscape scale, is another feature of the present land condition. This feature gives the cultivated fields and the landscape less of a monocultural appearance. These tree resources are consciously maintained by farming households and communities reflecting farmer indigenous knowledge [Vityakon 1993]. These trees serve farmers in various ways in their livelihoods [Grandstaff *et al*. 1986] as well as playing important ecological roles including land conservation [Vityakon 2001].

VII–4 *Implications and Recommendations*

Land degradation is the result of the land-use change occurring in the past century. However, degradation has not occurred equally in various land-use types and it is more severe in the uplands. In the past, when population density was low and unused land was still abundant, people could move to the frontier to clear new land so agriculture was extensive. However, the present trend in agricultural land use in the region is toward greater intensification as no more new land is available. In addition, maintaining productivity requires higher inputs. The land users are now faced with the problem of finding ways to keep the agroecosystem productive and sustainable. Reversion to polycultural agricultural systems, especially those with a tree component that mimic the natural systems is one possible solution. At the same time, a recommendation can be made about development of greater self-reliance of the sort that characterized the subsistence economy. This would reduce the need to produce such large quantities of cash crops in the uplands. Rather than relying to such a large extent on external inputs that must be purchased for cash as they do now, farmers would strive to meet a greater share of their consumption needs on their own farms. These two approaches are closely linked: polyculture tends to lead to ecological sustainability, while self-reliance is associated with sustainability in the socio-economic sense. In fact, the Northeast farm households have always remained subsistence and self-reliant with respect to their rice production. There has been some movement in the direction of polyculture and self-reliance already as the result of the promotion of integrated agriculture, (i.e. agricultural systems that have various kinds of interacting agricultural practices in a single farm. For example a farm can have fish raising in rice paddies plus farm pond for irrigation and fish raising plus poultry raising in pens situated over the farm ponds to enable the poultry droppings to feed the fish and plus fruit trees and multipurpose trees growing in paddy bunds and upland fields), and tree integration into farming systems. Both government agencies and NGOs have lately been promoting increasing tree resources in rural areas. Leading farmers (so-called indigenous intellectual farmers) in the Northeast have formed several networks to promote integrated farming and reduce dependency on commercial agriculture. Government agencies, notably the Royal Forest Department (RFD), have

lately promoted integration of trees into cultivated fields and community forestry by organizing farmer training and providing materials, such as seedlings. A most influential advocate of integrated farming and lesser dependency on commercial economy is the Thai King himself. He has suggested to his people in recent years that the nation should seek to keep one-forth of the economy, at all system hierarchical levels or scales, as subsistence-oriented while the rest can be integrated into the commercial (market) economy. By this he meant that, the one-quarter of the economy which does not rely on external factors can act as a buffer against changes in the influential external forces. The other 75% of the economy can function in propelling further growth of the cash economy—the dominant system in the modern world.

Land-use change in the past century has transformed the land cover of the Northeast from forest to agricultural fields, notably monocultural fields. Commercialization of the economy was the major factor that brought about this change, which, unfortunately, has been accompanied by serious land degradation. Reversing this trend is an urgent priority if development in the Northeast is to be sustainable. Replacement of monocultural agricultural systems with polycultural systems, especially those systems with tree components, and the adoption of a certain degree of subsistence orientation in the economy can help the Northeast to achieve ecological, economic and social sustainability in the new century.

Acknowledgements

This paper was born out of our studies in connection with the research project “Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand.” This project was funded by the National Research Council of Thailand and the Thailand Research Fund's Senior Research Fellow Program (awarded to Professor Aran Patanothai). Additional academic and financial support was provided by the Japan Society for Promotion of Science (JSPS). We appreciate the help of the following colleagues: Winit Youngme and Peangta Satarugsa of the Geotechnology Dept., Khon Kaen University for their expert help in characterizing the underlying rocks at the study site, Aran Patanothai and Kono Yasuyuki for their useful comments on the earlier version of the paper, A.Terry Rambo for many helpful discussions and editorial assistance, and Supaporn Pongkhaek for computer graphics. The senior author produced the first draft of the paper while she was a visiting scholar at the Laboratory of Tropical Forest Resources and Environments, Kyoto University. The support provided by the laboratory and her host scientist, Professor Watanabe Hiroyuki, is highly appreciated.

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